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Mirow

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(54) **LOW POWER INDUCTIVE PROXIMITY SENSING SYSTEM**

(71) Applicant: **Fred Mirow**, Lower Merion, PA (US)

(72) Inventor: **Fred Mirow**, Lower Merion, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 197 days.

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(22) Filed: **Sep. 24, 2013**

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(51) **Int. Cl.**

G01R 27/28	(2006.01)
G01D 5/20	(2006.01)
H03K 17/95	(2006.01)

(52) **U.S. Cl.**

CPC ***G01D 5/20*** (2013.01); ***H03K 17/951*** (2013.01); ***H03K 17/9525*** (2013.01)

(58) **Field of Classification Search**

CPC H03K 17/9547; G01B 7/023
USPC 324/207.15, 207.16, 207.26, 654; 340/686.1, 686.6, 941
See application file for complete search history.

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Primary Examiner — Melissa Koval
Assistant Examiner — Daniel Miller

(57) **ABSTRACT**

A low power inductive proximity sensing system in which a DC voltage to the inductors is only applied for a short time period needed to detect the presence or absence of an appropriate object. After the detection time period is over, DC voltage is no longer applied to the inductors.

4 Claims, 3 Drawing Sheets

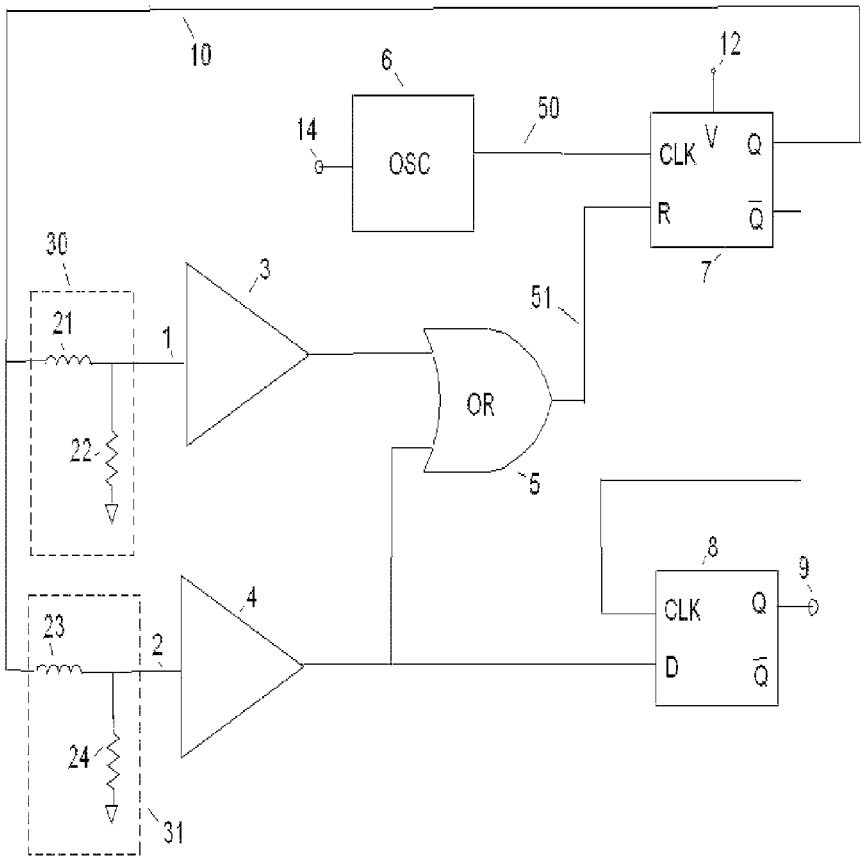


FIG. 1

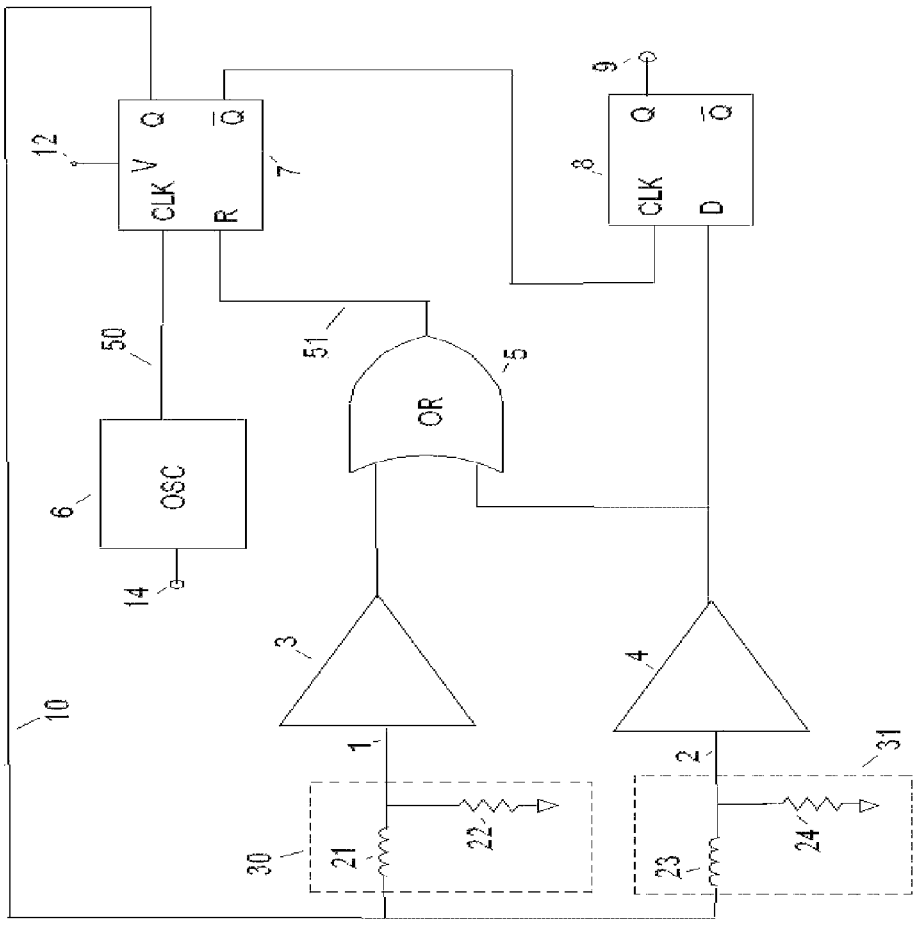

12
CLK
V
Q
$\overline{Q}$
R
7
9
8
CLK
D
Q
$\overline{Q}$
50
51
OR
5
6
OSC
14
3
4
10
1
2
31
30
21
22
23
24

FIG. 4

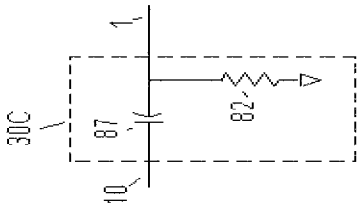


FIG. 3

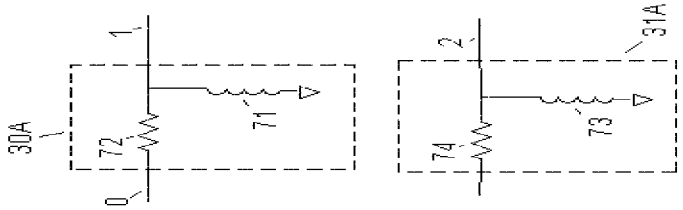


FIG. 2

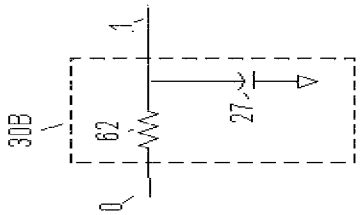


FIG. 5

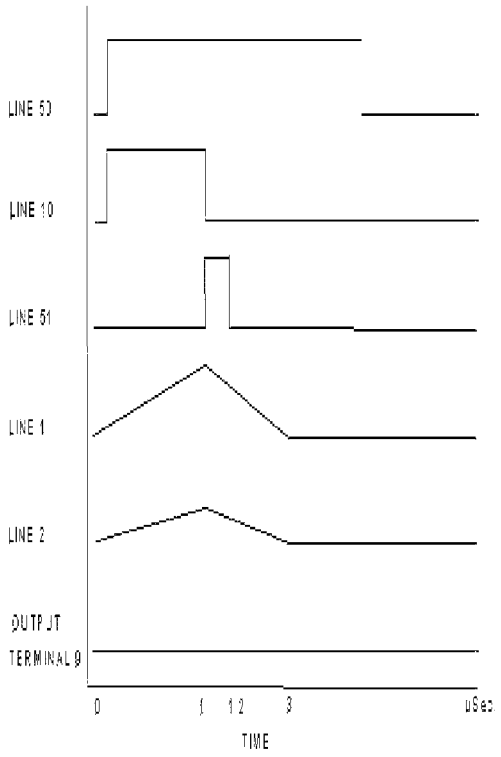
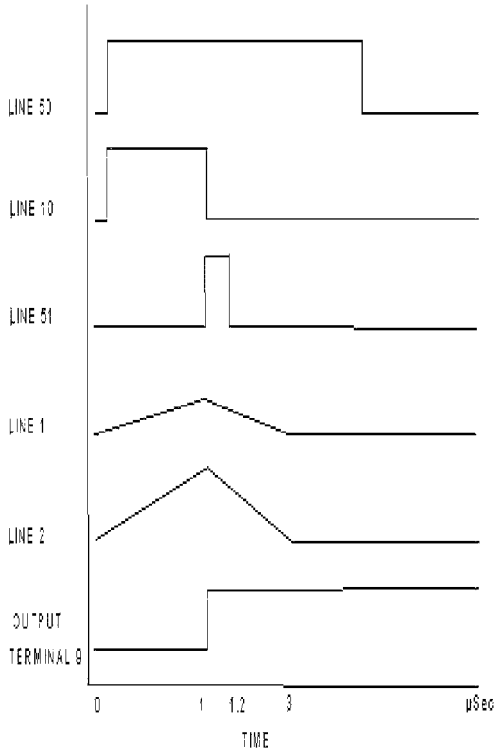

LINE 50
LINE 10
LINE 51
LINE 1
LINE 2
OUTPUT TERMINAL 9
0
1
1.2
3
μSec
TIME

FIG. 6


LINE 50
LINE 10
LINE 51
LINE 1
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TIME

LOW POWER INDUCTIVE PROXIMITY SENSING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The benefits of filing this invention as Provisional application for patent "LOW POWER INDUCTIVE PROXIMITY SENSING SYSTEM", U.S. PTO 61744390 filed Sep. 25, 2012 filed by Fred Mirow are claimed.

BACKGROUND OF THE INVENTION

The present invention relates to reducing the operating power of inductive proximity sensors.

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Presently available inductive proximity sensors require a high operating power which restricts their use in battery powered applications. The present invention uses reduced operating power by only applying power from a DC voltage supply to the inductor for a short time period needed to detect the presence or absence of an appropriate object. After the detection time period is over, DC voltage supply power is no longer applied to the inductor. As long as DC voltage supply power is applied to the inductor the current level increases. In the case of a capacitor the current level decreases with time. By waiting a relatively long time period between reapplication of DC voltage supply power to the inductor the power duty cycle is low causing the average power to be low. In addition by using CMOS logic circuitry which uses substantially no power, except during circuit signal level transitions, total sensor power is further reduced.

In addition the effects of temperature, supply voltage, and manufacturing tolerance can be reduced by using matched components and also ratios instead of absolute electrical values in the critical circuit sections. Most components especially those that are part of an Integrated Circuit can be readily built with a high level of electrical parameter matching while their absolute values have wide variations.

An objective of the present invention is to provide an inductive proximity sensor that operates at a low power level.

It is an additional object of the invention to provide an inductive proximity sensor that uses circuits that are less susceptible to process variances by relying on matched components and also ratios instead of absolute electrical values thereby providing a more consistently manufacturable circuit.

An additional object of the invention is to provide an inductive proximity sensor that uses circuits that have fast response time allowing a quick response to objects being sensed.

It is a further object of the invention to provide an inductive proximity sensor that uses circuits that are less susceptible to temperature and supply voltage variances by relying on matched components and also ratios instead of absolute electrical values.

BRIEF SUMMARY OF THE INVENTION

According to this invention, DC voltage supply power to the inductors is only applied for a short time period needed to detect the presence or absence of an appropriate object. After the detection time period is over, DC voltage supply power is no longer applied to the inductors. Most of the inductive proximity sensors power is used to operate the inductors. By powering the inductors for a relatively short time period and

then waiting a relatively long time period between reapplication of power to the inductors, the power duty cycle is low causing the inductive proximity sensors average power to be low. In addition by using CMOS logic circuitry which uses substantially no power, except during circuit signal level transitions, total sensor power is further reduced.

For best accuracy matched parts and using ratio of parts with matching temperature coefficients to determine circuit operation are used to build the critical circuits.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram illustrating an electrical configuration of a low power inductive proximity sensing system **1** according to a exemplary embodiment of the present invention,

FIG. **2** is a circuit diagram of Time Delay **30**B,

FIG. **3** is a circuit diagram of Time Delay **30**A and Time Delay **31**A,

FIG. **4** is a circuit diagram of Time Delay **30**C,

FIG. **5** is a timing diagram for low power inductive proximity sensing system **1** with the absence of an appropriate object sensed, and

FIG. **6** is a timing diagram for low power inductive proximity sensing system **1** with the presence of an appropriate object sensed.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** shows an exemplary low power inductive proximity sensing system **1** in accordance with an embodiment of the present invention. Flip Flop **7** receives input signals to its clock input from Oscillator **6** on line **50** and the reset input from the output of OR gate **5** on line **51**. Also terminal **12** is connected to a DC voltage supply. Level Detector **4** receives an input signal on line **2** and its output is connected to both Flip Flop **8** input D and also one of OR gate **5** inputs. Level Detector **3** receives an input signal on line **1** and its output is connected to the other OR gate **5** input.

The Q output of Flip Flop **7** is connected to line **10**. Flip Flop **7** Q bar output (Q with bar above it meaning having the inverted output signal level of Q) is connected to the clock input of Flip Flop **8**. The Q output of Flip Flop **8** is connected to output terminal **9**.

Time Delay **30** has one terminal of Inductor **21** connected to line **10**. The other terminal of Inductor **21** is connected to line **1**. One terminal of Resistor **22** is connected to line **1** and its other terminal is connected to ground.

Time Delay **31** has one terminal of Inductor **23** connected to line **10**. The other terminal of Inductor **23** is connected to line **2**. One terminal of Resistor **24** is connected to line **2** and its other terminal is connected to ground.

Level Detector **3** output changes from low to high level when the signal level on line **1** exceeds a set level and Level Detector **4** output changes from low to high level when the signal level on line **2** exceeds a set level. Preferably the set signal level of Level Detector **3** and **4** and their circuits are substantially the same to reduce the effects of temperature, supply voltage, and manufacturing tolerance. While comparators or CMOS inverters may be used to perform the function of Level Detector **3** and **4**, Schmidt trigger circuits are preferable because they use less power and have faster response time.

When either Level Detector **3** or **4** output signal changes from low to high level, the OR gate **5** output signal changes from low to high level causing the Q output of Flip Flop **7** to go to a low signal level and its Q bar output to a high signal

level. When the Flip Flop **7** Q bar output signal changes from low to high level, the output signal level of Level Detector **4** determines the Flip Flop **8** Q output until the next time Flip Flop **7** Q bar output signal changes from low to high level again. Flip Flop **8** Q output signal level is applied to output terminal **9**. The signal level at output terminal **9** indicates the presence or absence of an appropriate object.

Clock **6** generates a pulse output signal, which does not need be a square wave. When Clock **6** generates an output signal going to a high level, the Q output of Flip Flop **7** becomes a high signal level. When the Q output of Flip Flop **7** is a high signal level, voltage is applied from terminal **12** to line **10** and when the Q output is a low signal level, line **10** is substantially connected to ground.

The repetitive rate at which Clock **6** is set to generate a high output signal depends on the rate at which the object to be sensed is required to be sensed. For example Clock **6** may generate a high output signal of 1 micro second duration that has a repetitive rate of **10** times a second. The time period of Clock **6** output signal is under all conditions longer than the time required for the first of either Level Detector **3** or **4** output signal level to go high and then also for the voltage levels on lines **1** and **2** to have been significantly reduced towards 0 volts. It is also understood the repetitive rate maybe controlled by an external signal applied to terminal **14**.

Time Delay **30** provides a voltage level time delay between its input on line **10** and output on line **1**. The combination of Inductor **21** and Resistor **22** produces a time constant that is affected by the presence of an appropriate object which causes Inductor **21** to change inductance level. As the Inductor **21** inductance level increases, the time constant increases, and the voltage level rise time (which is the time required to reach a given voltage level on line **1**) increases. In the case where the Inductor **21** inductance level decreases, the voltage level rise time required to reach a given voltage level on line **1** decreases.

Time Delay **31** provides a voltage level time delay between its input on line **10** and output on line **2**. The combination of Inductor **23** and Resistor **24** produces a time constant that is affected by the presence of an appropriate object which causes Inductor **23** to change inductance level. As the Inductor **23** inductance level increases, the voltage level rise time required to reach a given voltage level on line **2** increases. In the case where the Inductor **23** inductance level decreases, the voltage level rise time required to reach a given voltage level on line **2** decreases.

In one example during operation one of either Inductor **23** or Inductor **21** is placed in proximity to the intended object to be sensed while the other Inductor is not. For an example Inductor **23** substantially matches Inductor **21**. Also Resistor **24** substantially matches Resistor **22** except that Resistor **22** has a slightly higher resistance value but substantially the same temperature coefficient.

In this example when Inductor **23** is not near the target Level Detector **3** output level becomes high before that of Detector **4** which causes output terminal **9** signal level to be low. As Inductor **23** approaches a target that lowers its inductance value Detector **4** output level becomes high before that of Detector **3** which causes output terminal **9** signal level to be high.

In another example Resistor **24** substantially matches Resistor **22** except that Resistor **24** has a slightly higher resistance value but substantially the same temperature coefficient. When Inductor **23** is not near the target Level Detector **4** output level becomes high before that of Detector **3** which causes output terminal **9** signal level to be high. As Inductor **23** approaches a target that increases its inductance value, Detector **3** output level becomes high before that of Detector **4** which causes output terminal **9** signal level to be low.

In some applications in which the best performance over a wide temperature range is required the object to be sensed can be physically moved so as to become closer to inductor **23** as it becomes further away from inductor **21**, or vice a versa.

In some other applications in which the best performance over a wide temperature range is not required Time Delay **30**B FIG. **2** can be used. Resistor **62** is connected between input line **10** and output on line **1**. Capacitor **27** is connected between output on line **1** and ground.

Time Delay **30**B provides a voltage level time delay between its input online **10** and output on line **1**. The combination of Capacitor **27** and Resistor **62** generates a fixed time constant. When using Time Delay **30**B, Inductor **23** is used to sense the target presence.

In some additional applications it may be preferable to have the voltage level on lines **1** and **2** decreases with time instead of increasing. In these applications Time Delay **30**A and **31**A in FIG. **3** can be used. Time Delay **31**A has Resistor **74** connected between input line **10** and output on line **1**. Inductor **73** is connected between output on line **1** and ground. Time Delay **30**A has Resistor **72** connected between input line **10** and output on line **1**. Inductor **71** is connected between output on line **1** and ground. It is understood in this case that the output signals of both level detector **3** and **4** would need to be inverted.

Time Delay **30**C FIG. **4** uses a capacitor to cause the voltage level on lines **1** to decrease with time instead of increasing. Time Delay **30**C has Capacitor **87** connected between input line **10** and output on line **1**. Resistor **82** is connected between output on line **1** and ground. It is understood in this case that the output signal of level detector **3** would need to be inverted.

FIG. **5** is a timing diagram for low power inductive proximity sensing system **1** in FIG. **1** with the absence of an appropriate object sensed. At time **0**, Clock **6** generates a output signal level going high on line **50** causing line **10** to have voltage applied to it. The voltage level on lines **1** starts to increase from 0 volts faster than that of line **2** with time. At 1 micro second the voltage level on line **1** exceeds the set level which causes Level Detector **3** output to change from low to high level and the signal level on line **51** goes high. The voltage applied to line **10** is now reduced to substantially 0 volts. The voltage level on line **2** did not exceed the set level which causes Level Detector **4** output to change from low to high level and the signal level at output terminal **9** remains low. The signal level on line **51** remains high level till 1.2 micro second at which time the voltage level on line **1** is below the set level causing Level Detector **3** output to change from high to low level. At 3 micro second the voltage levels on line **1** and **2** have returned to substantially 0 volts.

FIG. **6** is a timing diagram for low power inductive proximity sensing system **1** with the presence of an appropriate object causing the effective inductance of Inductor **23** to be reduced. At time **0**, Clock **6** generates a output signal level going high on line **50** causing line **10** to have voltage applied to it. The voltage level on lines **2** starts to increase from substantially 0 volts faster with time than that of line **1**. At 1 micro second, the voltage level on line **2** exceeds the set level which causes Level

Detector **4** output to change from low to high level and the signal level on line **51** goes high. The voltage applied to line **10** is now reduced to substantially 0 volts. Also, the signal level at output terminal **9** now becomes high. The voltage level on line **1** did not exceed the set level which causes Level Detector **3** output to change from low to high level. The signal

level on line **51** remains high level till 1.2 micro second at which time the voltage level on line **2** is below the set level causing Level Detector **4** output to change from high to low level. At 3 micro second, the voltage levels on line **1** and **2** have returned to substantially 0 volts.

The time values used in timing diagrams FIGS. **5** and **6** are just arbitrary values used to illustrate the system operation. In addition for clarity, the time delays of the individual circuit blocks are left out except for that of Time Delay **30** and **31**.

What is claimed is:

1. An inductive proximity detector comprising:

a first inductor and a second inductor wherein the inductance value of one or both of said first and second inductors varies in response to proximity of an object to be sensed;

first and second time delays comprising said first and second inductors, respectively;

a first time constant of said first time delay responsive to the inductance value of said first inductor;

a second time constant of said second time delay responsive to the inductance value of said second inductor;

an oscillator for controlling a time at which a DC voltage is applied to inputs of both said first and second time delays;

a first voltage level detector having a first output signal level responsive to said first time constant;

a second voltage level detector having a second output signal level responsive to said second time constant;

said first or second voltage level detector determining a time at which said DC voltage is no longer applied to both said first and second time delays;

a comparison circuit determining an output signal by comparing said first time constant to said second time constant, said output signal indicative of a presence or absence of said object to be sensed; and

said oscillator having a time period longer than said first time constant and said second time constant.

2. The oscillator of claim **1** having a repetitive rate controlled by an external signal.

3. An inductive proximity detector comprising:

an inductor wherein the inductance value of said inductor varies in response to proximity of an object to be sensed;

a first time delay comprising said inductor;

a second time delay circuit;

a first time constant of said first time delay responsive to said inductance value of said inductor;

a second time constant of said second time delay is substantially constant;

an oscillator for controlling a time at which a DC voltage is applied to inputs of both said first and second time delays;

a first voltage level detector having a first output signal level responsive to said first time constant;

a second voltage level detector having a second output signal level responsive to said second time constant;

said first or second voltage level detector determining a time at which said DC voltage is no longer applied to both said first and second time delays;

a comparison circuit determining an output signal by comparing said first time constant to said second time constant, said output signal indicative of a presence or absence of said object to be sensed; and

said oscillator having a time period longer than said first time constant and said second time constant.

4. The oscillator of claim **3** having a repetitive rate controlled by an external signal.

* * * * *